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OLDMAN RIVER DAM: MERCURY IN FISH - INTERIM REPORT 1992

Alberta
ENVIRONMENTAL CENTRE

OLDMAN RIVER DAM: MERCURY IN FISH - INTERIM REPORT 1992

by
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1 SUMMARY

Fish were collected during 1992 for analysis of mercury in muscle tissue from two sites on the Oldman River Dam Reservoir, two sites downstream of the reservoir on the Oldman River, one upstream site on the Oldman River, and one upstream site on the Crowsnest River. The species of fish collected for analysis were mountain whitefish, rainbow trout, bull trout, white sucker, longnose sucker, northern pike and burbot. Total mercury (THg) concentration in muscle tissue was assayed in 203 fish and organic mercury (OHg) concentration in 63 fish. Based on these collections, it was noted that:

i) bull trout, white sucker and longnose sucker carried slightly higher THg concentrations than the other species,

ii) mean THg concentrations were always <0.5 mg kg^{-1}, regardless of species or site,

iii) OHg accounted for 89-93% of total mercury, with a mean of 91%,

iv) although variable, THg concentrations in these 1992 collections were generally within the bounds of THg concentrations estimated for the same species collected from the same sites in 1991; after adjusting for size, THg in bull trout at one site below the dam was greater in 1992 than 1991, but at the same site, concentrations in longnose sucker had decreased. No other differences were detected between years.

It was concluded that mercury residues in fish from the reservoir and surrounding rivers posed no health threat to human consumers of fish.

2 INTRODUCTION

2.1 <u>Background</u>

In 1991, the Alberta Environmental Centre (AEC) initiated a five year research project on mercury in fish inhabiting the newly formed Oldman River Dam Reservoir and rivers within the Oldman River basin. The project, planned in association with two other government departments (Alberta Public Works, Supply and Services and Alberta Environmental Protection), formed part of a much larger fisheries mitigation strategy for the basin (Alberta Public Works, Supply and Services, 1990). This strategy requires that there be no net loss of fish habitat or recreational fishing opportunities, consistent with the government's policy of sustainable development.

The impetus for this project was the possibility that mercury concentrations in fish might increase after impoundment. Mercury, when found in fish, occurs primarily in an organic form (methyl mercury) that may effect the central nervous system of consumers. These effects, when fully manifested, induce a condition known as Minamata disease (Friel, 1974). The term Minamata refers to Minamata Bay (Japan), the site where the disease was first diagnosed in fish consumers during the 1950's. Minamata disease does not appear to have been reported in Canada.

Increases in mercury in fish have been noted in several reservoirs in Canada and elsewhere (Green, 1990; Jackson, 1988; Johnson *et al.*, 1991; Bodaly *et al.*, 1984; Abernathy and Cumbie, 1977), but has not been observed in fish from Alberta reservoirs (e.g. Alberta Environmental Centre, 1989). The mechanism for increased mercury uptake by fish appears to be based on enhanced activity of methylating bacteria and other microorganisms in freshly inundated soil (Cox *et al.*, 1979; Jackson, 1988, 1991). The rate of methylation and subsequent uptake by fish and other aquatic species depend on numerous factors, including redox potential of the sediment, binding of Hg^{2+} to sulphides, binding of OHg to FeOOH and MnOOH, microbiological activity, pH of the sediment and overlying water, mercury concentrations in water, temperature, and trophic conditions (Jackson, 1988, 1993; Berman and Bartha, 1986; Curtis, 1974; Hakanson, 1980). Since these factors may vary from reservoir to reservoir, the extent of mercury accumulation in fish is also variable. In the more serious cases where concentrations exceed the guideline of 0.5 mg kg^{-1} (in muscle tissue), human consumption of fish has been limited or totally restricted.

2.2 Objectives

The overall study has two objectives:

Primary - assess changes in the concentration of mercury in the muscle tissue of fish over a five year period in the Oldman Dam Reservoir, the Oldman River near the reservoir, and the Crowsnest River.

Secondary - conduct supplementary inventory studies of fish populations in the reservoir and surrounding rivers.

Fish collected during the first year of the study (1991) carried mean mercury concentrations that were always <0.5 mg kg^{-1}, regardless of species or site (Alberta Environmental Centre, 1993).

This specific report provides interim data for 1992, and comparisons with data from 1991 and earlier years.

3 CONDUCT OF STUDY

3.1 Good Laboratory Practice

It is recognized that potential increases in the concentration of mercury in fish might constitute a significant human health problem. Hence, the principles of Good Laboratory Practice (GLP) were implemented during 1992, and have and will continue to be used throughout the duration (5 years) of the study. Compliance with GLP is intended to ensure the quality and integrity of data generated for safety testing and litigation.

Guidance for GLP (including animal care and use, and data and sample tracking) is outlined in Standard Operating Procedures (Aquatic Biology Branch, 1991). These procedures are consistent with those outlined by other agencies (Federal Register, 1983; National Health and Welfare, 1989).

3.2 Project Team

A project team responsible for the execution of the protocol was formed and now includes the following staff (major duties in parenthesis):

J.W. Moore	Biological Sciences Division (Project Leader)
K.L. Smiley	Biological Sciences Division (Field Collection)
L.Z. Florence	Physical and Engineering Sciences Division (Statistical Design and Analysis)
S.Wu	Physical and Engineering Sciences Division (Analytical Methods)
D.S. Lucyk	Physical and Engineering Sciences Division (Laboratory Supervision and Analysis of Tissues).

All data and reports generated by this team are subject to the AEC review process.

3.3 Study Design and Sampling Methods

A complete description of the study design and sampling methods used in 1992 is outlined in Protocol 2440-DL2/P2 "Oldman River Dam: Mercury in Fish - 1992" Protocol. Copies of this protocol are available from the following address:

Central Records Office, Alberta Environmental Centre, Vegreville, AB, T9C 1T4, telephone (403) 632-8319.

The study design and sampling methods are substantially similar to those used during 1991 (Alberta Environmental Centre, 1993).

3.4 Method and Quality of Mercury Analysis

A complete description of the methods used to determine total and organic mercury is available in Alberta Environmental Centre (1993). Analytical quality for the 1992 data is described in Wu *et al.* (1993), also available from the following address:

Central Records Office, Alberta Environmental Centre, Vegreville, AB, T9C 1T4, telephone (403) 632-8319.

4 RESULTS

4.1 Species Inventory

A total of 203 fish was caught from the six sites (Figure 1, Table 1). Sites I and II (upstream of the reservoir) yielded 21.2% of the catch, Sites III and IV (within the reservoir) 48.3%, and Sites V and VI (downstream of the reservoir) 30.5%.

Three sport fish (bull trout *Salvelinus confluentus*; rainbow trout *Oncorhynchus mykiss*; mountain whitefish *Prosopium williamsoni*) made up 59.6% of the catch, while the corresponding frequency for suckers (white sucker *Catostomus commersoni*; longnose sucker *Catostomus catostomus*) was 39.4%. Only one northern pike (*Esox lucius*) and one burbot (*Lota lota*) were caught, both from Site VI.

Table 1. Distribution of 1992 fish catch among collection sites

SITE	LOCATION	NUMBER	PERCENT
I	Crowsnest River (Upstream)	30	14.8
II	Oldman River (Upstream)	13	6.4
III	Reservoir, West Basin	34	16.8
IV	Reservoir, East Basin	64	31.5
V	Oldman River, Below Dam	41	20.2
VI	Oldman River, Fort MacLeod	21	10.3
	TOTAL	203	100.0

4.2 Total Mercury Concentrations in Fish Muscle Tissue

Mean THg concentrations in fish were always <0.5 mg kg^{-1}, regardless of species or site (Appendix 1). Mountain whitefish generally contained the smallest concentrations, followed by rainbow trout. Although variable, concentrations in bull trout were generally higher than those of any other species.

4.3 Organic Mercury Concentrations in Fish Muscle Tissue

OHg was regressed against THg by the least squares regression method. The relationship using all samples was: OHg = 0.0032 + 0.8897 (THg). On average, then, OHg amounted to approximately 89% of THg with an error of 0.01. Among species, the OHg fraction of THg ranged from 89% to 93%, and 95% to 119% among sites (Table 2, Appendix 1).

4.4 Comparison of 1992 and 1991 Data at Different Sites

The following covariance model was used for comparison of adjusted means of THg of 1992 and 1991[1] data for each species:

THg = year + site + year x site + X (length) + random error

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[1]1991 data are in Alberta Environmental Centre (1993)

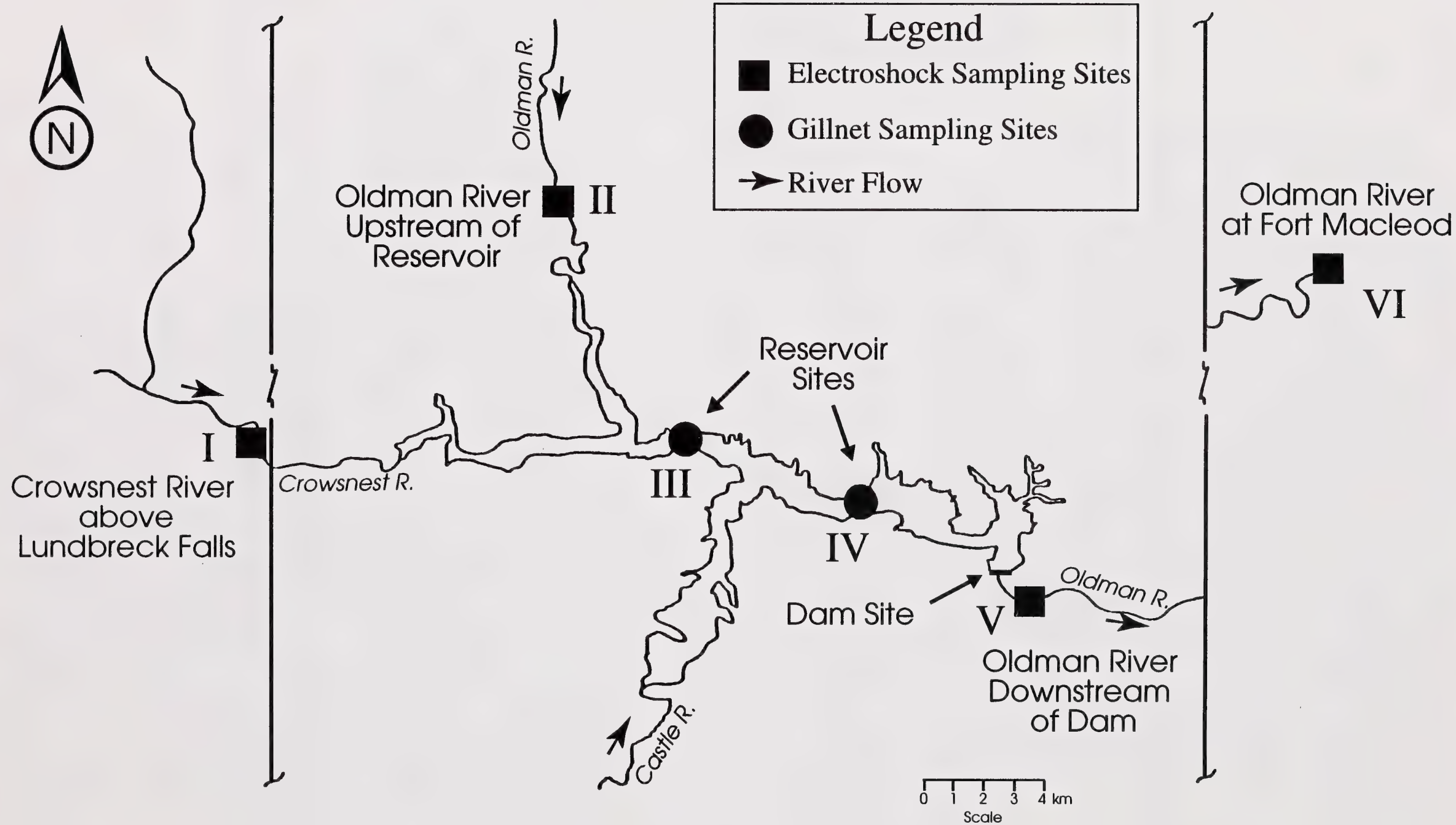

Figure 1. Collection sites I-VI

THg was used as the response variable because all fish were assayed for THg and it represented a reasonable estimate of organic mercury both from 1991 and 1992. Fork length (covariate) was used in the model because its coefficient of variation is about three times less than that of weight, and is easily determined with little error. Thus, THg means were compared by removing differences which would occur due to variation in fish size. (When not significant, length was removed from the model.)

There were only two means that were different among all combinations (Table 3). Residues in bull trout at site V were greater in 1992 than 1991, whereas in longnose sucker, they were greater in 1991 than 1992.

Table 2. Regression summary, OHg vs THg, by species, fitting model: OHg = b_0 + b_1 (THg) + error.

Species	N	$b_0(\pm SE)$	$b_1(\pm SE)$	$r^2(\%)$	$b_0 \neq 0$
Mountain Whitefish	13	0.0000(0.0074)	0.8972(0.0382)	97.7	No
Rainbow Trout	13	0.0068(0.0058)	0.8766(0.0201)	99.3	No
Bull Trout	15	0.0018(0.0110)	0.8845(0.0312)	98.2	No
White Sucker	4	0.0649(0.0260)	0.7664(0.0504)	98.3	No
Longnose Sucker	13	0.0033(0.0093)	0.9289(0.0285)	98.8	No

5 DISCUSSION

Since only two years of data are available, care must be taken when interpreting those results. Limnological conditions in the reservoir and Oldman River downstream of the reservoir are currently dynamic and will not stabilize for several years. As changes occur in physical and chemical conditions of the sediments and water column, the availability of organic mercury to aquatic organisms will also change.

Table 3. Means of THg (±SE) adjusted for fish size (fork length, when caught), for the primary species sampled among six sites within the Oldman Dam study area. Blanks are due to either no catch or insufficient data in each of the years at a given site.

Species	Year	Site					
		I	II	III	IV	V	VI
Mountain Whitefish	1991	0.048 (0.0155)	0.068 (0.0390)	0.166 (0.0146)	0.124 (0.0150)	0.111 (0.0111)	0.199 (0.0272)
	1992	0.034 (0.0173)	0.110 (0.0304)	0.111 (0.0298)	0.152 (0.0213)	0.087 (0.0236)	0.154 (0.0122)
Rainbow Trout	1991	0.050 (0.0175)	0.060 (0.0258)	0.318 (0.0191)	--	--	0.264 (0.0301)
	1992	0.0342 (0.0216)	0.123 (0.0417)	0.234 (0.0374)	--	--	0.308 (0.0483)
Bull Trout	1991	--	0.202 (0.0432)	0.290 (0.0329)	--	0.197 (0.0139)	0.223 (0.0228)
	1992	--	0.263 (0.0368)	0.275 (0.0384)	--	0.326* (0.0423)	0.278 (0.0353)
White Sucker	1991	--	--	0.355 (0.0305)	0.228 (0.0277)	0.218 (0.0209)	0.191 (0.024)
	1992	--	--	0.294 (0.0308)	0.335 (0.0428)	0.174 (0.0480)	0.181 (0.0340)
Longnose Sucker	1991	--	--	0.268 (0.0320)	--	0.199* (0.0162)	0.210 (0.0181)
	1992	--	--	0.323 (0.0270)	--	0.127 (0.0170)	0.182 (0.0219)

* Mean at a given site and year is greater than the other year's mean at the 0.05 level of significance. Number pair wise of comparisons among means per species are accounted for (Bonferroni adjustment) in order to keep the Type I error at the 0.05 level.

Perhaps the most important feature of the 1992 data is that mean THg concentrations were always low and <0.5 mg kg^{-1}, regardless of species or site. Although there were statistically significant changes in the concentrations of THg in two species from 1991 to 1992 (increase in bull trout, decrease in longnose sucker), the overall flux was relatively small and presented no environmental or health risk. The reasons for this flux in concentrations are unknown, but may simply represent natural variability within the system.

The differences in THg concentrations in bull trout and longnose sucker at Site V in the Oldman River basin may be due to a number of factors or combination of factors of both natural and anthropogenic origins, for example: i) rate of methylation of mercury as the river becomes more eutrophic moving downstream; ii) methylation of mercury as the river warms moving downstream; iii) changes in the physical and chemical properties of sediments, resulting in increased mobilization of inorganic and organic mercury; iv) change in the diet of fish, and (v) sampling artifacts. It is not possible to interpret this trend at the present time. This database will be enlarged over the next three years of the study, and further plans may be developed to test the contribution of the above-noted factors.

In 1986, Alberta Environment arranged for the collection of fish from the Oldman River system in the vicinity of the yet to be constructed Oldman River Dam (Alberta Environment, 1989). The aim of that study was to provide pre-impact data for comparison with post-impoundment data. The results of the 1986 study are summarized here, and compared with our 1992 data. THg and OHg analyses were completed on the dorsal muscle tissue of the 1986 fish. Some of the collection sites were similar to those used in this study whereas others were located on the Castle River, which was not included in this study (Appendix 2). Mercury concentrations in these fish were generally similar to those found in this study (Appendix 3). Rainbow trout and mountain whitefish carried the lowest concentrations, while white sucker, longnose sucker and bull trout generally had higher levels. Concentrations in the primary game species (bull trout, rainbow trout, mountain whitefish) were always <0.5 mg kg^{-1}, while in the 1992 study, only one bull trout had >0.5 mg kg^{-1}. The 1991 study yielded three rainbow trout and two white suckers at >0.5 mg kg^{-1}.

In conclusion, THg and OHg residues in fish collected during 1992 from the reservoir and surrounding rivers were low and posed no threat to human consumers of fish. THg concentrations in the 1992 collections were generally within the bounds of THg estimated for the same species in 1991 and 1986.

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Appendix 1. Summary of unadjusted mercury concentrations in muscle tissue of fish collected from the Oldman River Dam area in 1992§

Site	Species*	Length			Total Mercury			Organic Mercury			N of Total Mercury ≥0.5 mg kg^{-1}
		N	Fork Length (cm)		N	Concentration (mg kg^{-1})		N	Concentration (mg kg^{-1})		
			Mean	Range		Mean	Range		Mean	Range	
Site I Crowsnest River, above Lundbreck Falls	RNTR	15	29.3	19.0-39.1	15	0.032	0.013-0.049		--	--	0
	MNWH	15	29.0	19.1-36.8	15	0.035	0.019-0.050	1	0.048	--	0
Site II Oldman River, upstream of reservoir	RNTR	4	28.7	21.0-35.8	4	0.120	0.038-0.295	3	0.134	0.069-0.249	0
	MNWH	5	33.2	29.9-36.5	5	0.114	0.042-0.181	2	0.149	0.141-0.156	0
	BLTR	4	34.9	23.7-41.7	4	0.273	0.122-0.411	4	0.237	0.120-0.334	0
Site III Reservoir, west basin	RNTR	1	47.7	--	1	0.346	--	1	0.299	--	0
	MNWH	7	29.3	21.0-39.2	7	0.100	0.037-0.250	2	0.152	0.063-0.241	0
	BLTR	3	33.2	30.0-35.1	3	0.328	0.274-0.371	3	0.296	0.235-0.346	0
	WHSC	4	37.2	35.7-40.0	4	0.193	0.088-0.255		--	--	0
	LNSC	19	32.4	25.9-42.0	19	0.223	0.149-0.339	1	0.233	--	0
Site IV Reservoir, central basin	RNTR	4	44.6	43.9-45.4	4	0.334	0.140-0.449	4	0.303	0.129-0.398	0
	MNWH	33	21.5	16.5-29.5	33	0.172	0.046-0.375	5	0.194	0.104-0.265	0
	BLTR	4	43.0	32.8-59.0	4	0.400	0.258-0.623	4	0.363	0.229-0.566	1 (1)‡
	WHSC	8	36.8	34.5-39.3	8	0.196	0.146-0.279		--	--	0
	LNSC	15	28.8	22.2-43.6	15	0.238	0.146-0.367	4	0.208	0.150-0.241	0
Site V Oldman River, immediately below dam	RNTR	5	32.6	25.0-37.9	5	0.238	0.058-0.375	5	0.213	0.056-0.328	0
	MNWH	5	28.0	22.3-30.9	5	0.112	0.063-0.141	3	0.113	0.101-0.126	0
	BLTR	5	45.1	40.8-47.0	5	0.339	0.280-0.405	5	0.300	0.246-0.349	0
	WHSC	10	38.6	34.0-44.9	10	0.322	0.111-0.531	4	0.425	0.387-0.473	1 (1)‡
	LNSC	16	44.4	38.1-49.5	16	0.338	0.181-0.484	6	0.325	0.169-0.459	0
Site VI Oldman River, Fort MacLeod	RNTR	1	25.3	--	1	0.315	--	1	0.297	--	0
	MNWH	10	30.0	24.8-41.1	10	0.154	0.104-0.329	1	0.279	--	0
	WHSC	5	36.1	32.9-41.3	5	0.345	0.243-0.658	1	0.573	--	1 (1)‡
	LNSC	3	38.7	35.0-41.6	3	0.337	0.140-0.466	3	0.311	0.122-0.428	0
	NRPK	1	50.8	--	1	0.321	--		--	--	0
	BURB	1	52.0	--	1	0.381	--		--	--	0

§ Analysis performed by snipping subsampling procedure.
‡ Denotes number of fish ≥0.44 mg kg^{-1} (snipped and also ≥0.5 mg kg^{-1} (homogenized).

* RNTR - Rainbow Trout
MNWH - Mountain Whitefish
BLTR - Bull Trout
WHSC - White Sucker
LNSC - Longnose Sucker
NRPK - Northern Pike
BURB - Burbot

Appendix 2. Fish sampling sites and locations of 1986, 1991 and 1992

1986			1991 & 1992			
Location Description	Distance (km)	Note	Site	Location Description	Distance (km)	Note
Castle River (below FSL)	9.7 - 14.9	(a)				
Castle River (above FSL)	14.9 - 24	(a)				
Crowsnest River (below FSL)	0 - 4.1	(b)				
Crowsnest River (below FSL)	4.1 - 9.1	(b)				
Crowsnest River (above FSL)	12.6 - 15.4	(b)				
			Site I	Crowsnest River, above Lundbreck Falls	40	(b)
			Site II	Oldman River, upstream of Reservoir	368	(c)
			Site III	Oldman Reservoir, West Basin	352	(c)
Oldman River (below FSL)	345 - 351	(c)	Site IV	Oldman Reservoir, Central Basin	345	(c)
Oldman River (above FSL)	331 - 339	(c)	Site V	Oldman River, immediately below dam	334	(c)
Oldman River downstream (above FSL)	270 - 316	(c)	Site VI	Oldman River, Fort MacLeod	270	(c)

(a) Distance in kilometres upstream of confluence with Oldman River.
(b) Distance in kilometres upstream of confluence with Oldman River.
(c) Distance in kilometres upstream of confluence with Bow River.
FSL Full Service Level.

Appendix 3. Summary of unadjusted mercury concentrations in muscle tissue of fish collected from the Oldman River (current dam area) in 1986 (Alberta Environment, 1989)

Location	Species*	Length			Total Mercury			Organic Mercury			N of Total Mercury ≥0.5 mg kg^{-1}
		N	Fork Length (cm)		N	Concentration (mg kg^{-1})		N	Concentration (mg kg^{-1})		
			Mean	Range		Mean	Range		Mean	Range	
Castle River (below FSL)	RNTR	5	29.6	26.4-35.5	5	0.157	0.076-0.270	5	0.146	0.065-0.250	0
	MNWH	6	31.7	28.2-38.1	6	0.190	0.077-0.290	6	0.171	0.062-0.274	0
	BLTR	4	31.9	27.9-35.3	4	0.192	0.177-0.206	4	0.188	0.171-0.202	0
	WHSC	3	37.1	35.2-39.2	3	0.312	0.230-0.420	3	0.307	0.225-0.414	0
Castle River (above FSL)	RNTR	5	28.7	23.9-34.6	5	0.168	0.086-0.305	5	0.162	0.081-0.301	0
	MNWH	5	29.2	24.6-38.8	5	0.126	0.083-0.161	5	0.122	0.078-0.157	0
	LNSC	10	40.5	36.1-42.7	10	0.355	0.260-0.470	10	0.348	0.255-0.461	0
Crowsnest River (below FSL)	RNTR	4	37.5	33.2-38.9	4	0.158	0.081-0.236	4	0.154	0.079-0.229	0
	MNWH	5	35.7	33.3-39.7	5	0.107	0.078-0.129	5	0.104	0.076-0.125	0
	WHSC	2	34.9	33.5-36.2	2	0.217	0.176-0.257	2	0.215	0.174-0.255	0
	LNSC	5	45.2	43.9-45.7	5	0.426	0.362-0.257	5	0.422	0.359-0.488	0
Crowsnest River (below FSL)	RNTR	3	33.5	32.8-33.9	3	0.187	0.113-0.224	3	0.184	0.111-0.222	0
	MNWH	5	33.4	31.5-35.9	5	0.172	0.115-0.250	5	0.170	0.112-0.248	0
	WHSC	4	34.6	32.7-35.5	4	0.366	0.142-0.509	4	0.363	0.140-0.506	2
	LNSC	6	42.6	37.7-54.7	6	0.316	0.241-0.343	6	0.314	0.239-0.340	0
Crowsnest River (above FSL)	RNTR	5	34.2	33.0-37.8	5	0.118	0.077-0.160	5	0.115	0.075-0.157	0
	WHSC	1	41.4	--	1	0.518	--	1	0.516	--	1
Oldman River (below FSL)	RNTR	2	28.7	20.3-37.0	2	0.194	0.110-0.278	2	0.192	0.108-0.276	0
	MNWH	2	27.7	27.3-28.0	2	0.181	0.162-0.200	2	0.179	0.160-0.197	0
	LNSC	4	39.9	38.5-42.6	4	0.379	0.302-0.510	4	0.376	0.299-0.507	1
Oldman River (above FSL)	RNTR	2	27.1	27.1-27.1	2	0.169	0.160-0.178	2	0.168	0.159-0.176	0
	MNWH	9	25.5	22.9-34.1	9	0.145	0.086-0.406	9	0.143	0.085-0.402	0
	BLTR	1	36.5	--	1	0.304	--	1	0.303	--	0
	LNSC	3	41.1	38.3-45.1	3	0.405	0.290-0.528	3	0.404	0.289-0.527	1
Oldman River Downstream (above FSL)	RNTR	7	35.6	31.4-39.6	7	0.176	0.092-0.285	7	0.174	0.090-0.284	0
	MNWH	11	35.1	29.3-41.3	11	0.153	0.072-0.312	11	0.149	0.070-0.308	0
	WHSC	11	42.8	40.4-46.1	11	0.556	0.320-0.750	11	0.553	0.318-0.747	7
	LNSC	11	41.5	38.9-45.6	11	0.316	0.113-0.442	11	0.313	0.110-0.439	0

* See Appendix 1 for abbreviation of species.